IMPACT OF LIGHT POLLUTION ON ENERGY EFFICIENCY

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Abstract

This paper examines the impact of light pollution on energy efficiency with a focus on the European context. Light pollution, caused by excessive and mismanaged artificial lighting, contributes not only to ecological degradation but also to unnecessary energy waste and increased greenhouse gas emissions. The analysis draws on existing literature, case studies, and European policy frameworks to identify effective strategies for addressing this issue. Results highlight three main areas: the potential of reducing electricity demand through efficient lighting design and smart management systems, the integration of renewable energy sources such as solar power into urban lighting infrastructures, and the role of technological advancements in LEDs and adaptive control systems. Case studies from European cities, along with projects in environmentally sensitive regions, demonstrate measurable energy savings and ecological benefits. Policy directives provide the regulatory basis, though challenges in implementation and public awareness remain. Overall, the findings suggest that mitigating light pollution represents both an environmental necessity and an economic opportunity, supporting sustainable urban development and improved quality of life.

Key words

Light pollution, energy efficiency, smart lighting, renewable energy, urban sustainability

1. Introduction

The impact of light pollution on energy efficiency has globally become an increasingly pressing issue, reflecting the broader challenge of balancing urban development, environmental protection, and sustainable energy management. Light pollution, generally understood as the alteration of natural night light levels by artificial sources, currently affects nearly 80% of the global population, and the extent of artificially illuminated areas continues to grow at an estimated annual rate of 2.2% [1,2]. This expansion is driven primarily by widespread use of outdoor lighting such as street lamps, illuminated advertisements, and residential lighting systems, which, while intended to enhance safety, comfort, and commercial visibility, also generate substantial unintended consequences. These consequences include the disruption of natural ecosystems, the unnecessary expenditure of energy resources, and the resulting increase in greenhouse gas emissions and municipal costs [3–5].

The connection between light pollution and energy inefficiency is particularly relevant in the context of urban planning and environmental sustainability. Inadequately designed or poorly regulated lighting systems intensify energy consumption by producing excessive illumination, often in locations or at times where it is neither needed nor beneficial. Such inefficiency translates into considerable economic losses for cities and regions, since municipal budgets must cover the costs of electricity wasted by mismanaged lighting infrastructures. At the same time, these systems exacerbate carbon emissions, thereby undermining global and EU-level objectives to reduce environmental impact and combat climate change [3–5]. From an economic standpoint, existing research highlights that investments in energy efficiency measures, including optimized lighting technologies, can generate substantial long-term returns, with estimates suggesting that each euro invested in industrial energy efficiency may yield up to four euros in savings [6,7]. This evidence underlines the financial rationale for integrating light pollution mitigation into broader energy policies.

Beyond economic and energy-related considerations, the ecological implications of light pollution further emphasize the urgency of addressing this issue. Artificial night lighting disrupts wildlife behavior, affects species' reproductive cycles, and reduces biodiversity in both terrestrial and aquatic ecosystems, thereby compounding the environmental costs of inefficient energy use [2,4]. These ecological disruptions, when combined with rising energy demand, highlight the multidimensional nature of the challenge: energy efficiency cannot be pursued in isolation, but must instead be integrated with environmental and social dimensions of sustainability.

Mitigation strategies that target both light pollution and energy efficiency have shown promising results in practice. The adoption of energy-efficient lighting solutions, such as LED technologies with high luminous efficacy and long lifespans, has already demonstrated significant reductions in both energy consumption and excessive light emissions [8–10]. Furthermore, the implementation of smart lighting controls—such as adaptive dimming systems and occupancy-based sensors—has proven effective in minimizing unnecessary illumination while preserving the quality and safety of lighting environments [8–10]. Several European municipalities have successfully piloted these approaches, with case studies in Chiasso and Massagno serving as notable examples of how innovative solutions can achieve substantial energy savings while simultaneously enhancing urban ecosystems and reducing environmental stress [10].

Despite these advancements, considerable barriers remain to achieving large-scale improvements in energy efficiency through light pollution mitigation. The lack of comprehensive regulatory frameworks often results in fragmented and inconsistent policies across regions, which limits the scalability of successful local initiatives. Moreover, low levels of public awareness and insufficient stakeholder engagement pose additional challenges, as collective efforts are essential for ensuring the effectiveness of technological and regulatory measures [11].

In summary, light pollution represents not only an environmental concern but also a critical challenge to energy efficiency, with significant consequences for economic viability, public policy, and ecological health. The issue requires coordinated responses at multiple levels, encompassing technological innovation, legislative frameworks, and community participation. By addressing the problem holistically, the EU and other regions can move toward creating sustainable urban environments that minimize both unnecessary energy waste and ecological disruption, thereby aligning energy efficiency objectives with broader sustainability goals.

2. Methodology

This paper is based on a structured review of existing literature, case studies, and policy documents addressing the relationship between light pollution and energy efficiency. The aim of the methodology is to combine technical insights, practical experiences, and regulatory perspectives in order to present a comprehensive view of the topic.

The first step consisted of reviewing academic and technical publications on energy-efficient lighting technologies. These include recent comprehensive studies that summarize the development of LED systems, smart lighting controls, and their role in reducing energy consumption

The second step focused on practical evidence from case studies. Projects implemented in European cities, such as Barcelona, provide real data on how intelligent public lighting strategies reduce electricity demand while improving environmental performance. Further examples also highlight the relevance of energy-efficient lighting in environmentally sensitive areas, such as the Galapagos Islands, where sustainable lighting solutions were introduced to minimize ecological disruption. [12,13]

In addition to technological and practical sources, the analysis incorporated European policy documents and directives. The Energy Efficiency Directive (EED) establishes binding targets for reducing energy consumption across the EU [14]. Complementary frameworks, such as the Energy Performance of Buildings Directive (EPBD) and the Ecodesign Directive, further support the shift toward efficient lighting in both public spaces and building design [15,16].

Finally, contextual studies on light pollution and its broader impacts were included to underline why energy efficiency in lighting is not only a technical matter but also an environmental and social concern. Sources addressing the ecological consequences of artificial night lighting and strategies for reducing light pollution provide the necessary background for linking energy use with sustainability outcomes [17–19].

3. Results and Discussion

The findings from the reviewed literature, case studies, and policy documents provide a multifaceted picture of the relationship between light pollution and energy efficiency. Rather than focusing solely on the negative effects of excessive artificial lighting, the discussion explores how specific measures can both reduce energy consumption and mitigate environmental impacts. The results are organized into four thematic areas that emerged from the analyzed sources: reduction of energy consumption, integration of renewable energy sources, technological advancements in lighting, and the role of policy and regulation. In addition, the broader ecological, economic, and social implications are considered.

The following subsections present these perspectives in more detail, supported by examples from European practice and relevant international studies.

3.1 Energy Consumption Reduction

Artificial lighting represents a significant share of total electricity demand, particularly in urban areas where street lighting and public infrastructure operate continuously. Recent reviews highlight that efficient lighting technologies, especially LEDs combined with smart control systems, can reduce consumption in the range of 28% to 40% in typical applications [20] These savings not only lower operational costs but also directly address the problem of light pollution by minimizing unnecessary emissions of artificial light into the environment.

Practical experience confirms the theoretical potential. In the Barcelona metro network, the introduction of occupancy-based dimming controls reduced electricity consumption by more than one third compared to baseline values. The system achieved savings of 36.22% while maintaining adequate illumination levels for passenger safety [12]. Similar results have been reported in other European municipalities where smart lighting has replaced conventional streetlights.

From a regulatory perspective, the European Energy Efficiency Directive provides a framework that encourages municipalities to implement such measures. It sets binding targets for energy savings, pushing cities and public authorities to adopt efficient lighting as part of broader energy management strategies [14,21]

In summary, energy consumption reduction is the most immediate and measurable benefit of addressing light pollution through improved lighting design. Lower demand for electricity translates into reduced operating costs, lower greenhouse gas emissions, and a more sustainable urban environment.

3.2 Integration of Renewable Energy Sources

Reducing energy consumption is only one part of the solution; integrating renewable energy sources into lighting systems further strengthens the link between energy efficiency and sustainability. Daylight utilization plays a central role in this regard. Studies show that when natural solar radiation is effectively incorporated into building design, the reliance on artificial lighting decreases considerably, leading to measurable reductions in electricity demand [17].

Hybrid systems combining solar power with LED technology have demonstrated superior performance compared to traditional lighting solutions. Such configurations provide stable illumination while simultaneously lowering grid dependency and operating costs [20]. In practice, photovoltaic installations on public buildings and urban infrastructure have been widely adopted as part of the European transition to renewable energy. The Energy Performance of Buildings Directive (EPBD 2024/1275) explicitly encourages the integration of photovoltaics into building envelopes to achieve higher energy efficiency and lower carbon emissions [15].

A notable example of renewable integration can be found in projects implemented in environmentally sensitive areas. The introduction of solar-powered LED systems in the Galapagos Islands reduced the environmental footprint of public lighting while maintaining high-quality illumination for residents and visitors [13]. This case illustrates how renewable integration not only reduces energy use but also contributes to preserving biodiversity and minimizing ecological disturbance.

Overall, the integration of renewable energy sources into lighting design extends the impact of efficiency measures. It directly links energy savings with climate goals, making lighting a central element in the broader shift toward sustainable urban infrastructure.

3.3 Technological Advancements in Lighting

Technological development in lighting has been one of the most effective tools for improving energy efficiency while simultaneously reducing light pollution. The most prominent shift has been the large-scale transition from incandescent and fluorescent lamps to LED technology. LEDs are characterized by significantly higher luminous efficacy (over 120 lm/w) [22], longer lifetime, and greater flexibility in design, which makes them the dominant solution for both public and private applications [23,24].

In addition to the hardware itself, innovative lighting control systems have emerged as a key factor in optimizing energy use. Adaptive systems equipped with sensors can adjust illumination according to occupancy, traffic flow, or environmental conditions. This approach reduces unnecessary lighting, lowers operating costs, and enhances user comfort. The application of these systems has been widely demonstrated in European pilot projects, showing both energy savings and improved quality of urban nightscapes [25,26].

Further technological progress involves new optical designs, high-efficiency reflectors, and intelligent control algorithms. These developments allow lighting to be directed more precisely, reducing spillover and skyglow, which are major contributors to light pollution. The adoption of Ecodesign Directive requirements ensures that such innovations are not only technologically feasible but also embedded into European product standards [27,28].

Evidence from municipalities such as Chiasso and Massagno, where conventional luminaires were replaced with modern LED systems, shows that technological upgrades can deliver substantial reductions in energy consumption while improving nighttime visibility and reducing environmental impact [13].

In summary, advancements in lighting technology represent the technical backbone of efforts to simultaneously increase energy efficiency and limit light pollution. When combined with renewable energy integration and smart management, these innovations offer a pathway toward sustainable and resilient urban lighting systems.

3.4 Policy and Regulation Perspective

Technological progress and practical case studies show clear potential for improving energy efficiency and reducing light pollution, yet without a strong regulatory framework, implementation often remains limited. In the European Union, several directives provide the foundation for action in this area. The Energy Efficiency Directive (EED) establishes binding energy-saving targets and requires member states to adopt measures that include improvements in public lighting systems [14,21]. The directive highlights the importance of reducing electricity demand in municipalities, making lighting upgrades one of the most cost-effective strategies.

Complementary frameworks strengthen this approach. The Energy Performance of Buildings Directive (EPBD 2024/1275) promotes the integration of renewable energy and efficient technologies in building design, directly linking daylight use, photovoltaics, and efficient luminaires with broader energy goals [15]. Similarly, the Ecodesign Directive sets minimum efficiency requirements for lighting products, ensuring that the transition toward energy-efficient solutions is embedded into the European market [16].

Recent policy analyses further emphasize the exemplary role of public buildings. According to a 2025 policy brief, the renovation of public facilities and the adoption of efficient lighting technologies demonstrate good practice and encourage wider replication across municipalities [29]. This highlights the role of local governments not only as implementers but also as leaders in raising awareness.

Despite these advances, challenges remain. National implementations of European directives are not uniform, and in some regions, awareness of light pollution as an environmental problem is still limited. Moreover, financial and administrative barriers can slow down the adoption of efficient technologies, particularly in smaller municipalities. These gaps underline the need for stronger coordination and incentives to ensure that policy frameworks translate into measurable reductions in energy consumption and light pollution.

3.5 Broader Implications

The interplay between light pollution and energy efficiency extends beyond technical and regulatory aspects, encompassing environmental, economic, and social dimensions. From an environmental perspective, excessive artificial lighting disrupts ecosystems, alters wildlife behavior, and contributes to biodiversity loss. Reducing unnecessary lighting not only saves energy but also preserves nocturnal environments, aligning with broader sustainability goals [17,19].

Economically, improved lighting systems directly lower operational costs for municipalities and private entities. Case studies have shown that investments in smart lighting and LED technology result in significant long-term savings, with reduced maintenance needs adding further benefits [30,31].These savings can be reinvested in other sustainability initiatives, amplifying the positive impact.

Socially, reducing light pollution contributes to higher quality of life in urban areas. Darker skies improve well-being, strengthen the cultural connection to the natural environment, and create healthier living conditions by minimizing light-related disturbances to circadian rhythms. Initiatives such as the dark-sky movement demonstrate how public awareness and community engagement play a critical role in fostering changev [32].

Taken together, these broader implications emphasize that addressing light pollution is not only a matter of energy efficiency. It is a multidisciplinary challenge with the potential to deliver ecological protection, economic resilience, and social benefits. Recognizing these dimensions helps ensure that strategies for reducing light pollution are supported by diverse stakeholders and contribute to long-term sustainability.

4. Conclusion

This paper has examined the relationship between light pollution and energy efficiency through a review of existing literature, case studies, and European regulatory frameworks. The findings indicate that reducing artificial lighting demand is a key driver of both economic savings and environmental protection. Case studies, such as the Barcelona metro and projects in environmentally sensitive areas, demonstrate that intelligent lighting management and the adoption of LED systems can deliver substantial energy savings while improving nighttime environments.

The integration of renewable energy sources, particularly photovoltaics and daylighting strategies, further enhances the efficiency of lighting systems and aligns with broader climate goals. At the same time, technological advancements in LEDs, adaptive controls, and efficient optical designs provide the technical foundation for minimizing unnecessary illumination and reducing the negative effects of light pollution.

Policy frameworks, including the Energy Efficiency Directive, the Energy Performance of Buildings Directive, and the Ecodesign Directive, create a strong regulatory basis for implementation. However, uneven national adoption and limited public awareness remain obstacles to widespread success. Strengthening coordination across different levels of governance and increasing incentives for municipalities are essential to ensure measurable results.

Beyond technical and regulatory aspects, the broader implications highlight that addressing light pollution improves ecological resilience, reduces operational costs, and enhances quality of life in urban areas. For this reason, reducing light pollution should be viewed not only as an energy-saving strategy but also as a step toward sustainable and healthier cities.

Future research and policy efforts should focus on expanding pilot projects, integrating advanced smart systems, and raising awareness among citizens and decision-makers. Only through combined technological, political, and social action can light pollution be effectively mitigated while achieving substantial improvements in energy efficiency.

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References

[1] Falchi F, Furgoni R, et al. Light pollution in USA and Europe: The good, the bad and the ugly. Journal of Environmental Management 2019;248:109227. https://doi.org/10.1016/j.jenvman.2019.06.128.
[2] ETC HE Report 2022/8: Review and Assessment of Available Information on Light Pollution in Europe. n.d.
[3] Causes of increasing light pollution 2025. https://www.gfz.de/en/press/news/details/ursachen-der-zunehmenden-lichtverschmutzung (accessed September 2, 2025).
[4] ltd R and M. Europe Lighting Fixtures Market Outlook, 2029 n.d. https://www.researchandmarkets.com/reports/5984927/europe-lighting-fixtures-market-outlook (accessed September 2, 2025).
[5] The evolution of public lighting, from torches to smart services. Energy Cities 2023. https://energy-cities.eu/the-evolution-of-public-lighting-from-torches-to-smart-services/ (accessed September 2, 2025).
[6] Keeping light under control. Narodowe Centrum Nauki n.d. https://ncn.gov.pl/en/aktualnosci/2025-03-20-swiatlo-pod-kontrola (accessed September 2, 2025).
[7] Public lighting | EUCF n.d. https://www.eucityfacility.eu/public-lighting (accessed September 2, 2025).
[8] How light pollution is damaging our cities - Paradox Engineering 2025. https://www.pdxeng.ch/how-light-pollution-is-damaging-our-cities/ (accessed September 2, 2025).
[9] Ministry of the Environment of the Czech Republic. Light pollution reduction measures in Europe. International Workshop on Light Pollution 2022, Prague, Czechia: n.d.

[10]Association TLI. Dark Skies: The Impact of Light Pollution in Cities n.d. https://www.thelia.org.uk/resource/dark-skies-the-impact-of-light-pollution-in-cities.html (accessed September 2, 2025).
[11]Paris public lighting. Energy Cities n.d. https://energy-cities.eu/best-practice/paris-public-lighting/ (accessed September 2, 2025).
[12]Casals M, Gangolells M, et al. Reducing lighting electricity use in underground metro stations. Energy Conv Manag 2016;119:130–41. https://doi.org/10.1016/j.enconman.2016.04.034.
[13]Velásquez C, Espín F, et al. Energy Efficiency in Public Lighting Systems Friendly to the Environment and Protected Areas. Sustainability 2024;16:5113. https://doi.org/10.3390/su16125113.
[14]Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast) (Text with EEA relevance). vol. 231. 2023.
[15]Directive - EU - 2024/1275 - EN - EUR-Lex n.d. https://eur-lex.europa.eu/eli/dir/2024/1275/oj/eng (accessed September 2, 2025).
[16]Directive - 2009/125 - EN - EUR-Lex n.d. https://eur-lex.europa.eu/eli/dir/2009/125/oj/eng (accessed September 2, 2025).
[17]Gaston KJ, Davies TW, et al. REVIEW: Reducing the ecological consequences of night-time light pollution: options and developments. Journal of Applied Ecology 2012;49:1256–66. https://doi.org/10.1111/j.1365-2664.2012.02212.x.
[18]Light is Energy: Estimating the Impact of Light Pollution on Climate Change. DarkSky International 2022. https://darksky.org/news/light-is-energy-estimating-the-impact-of-light-pollution-on-climate-change/ (accessed September 2, 2025).
[19]Falchi F, Cinzano P, et al. Limiting the impact of light pollution on human health, environment and stellar visibility. Journal of Environmental Management 2011;92:2714–22. https://doi.org/10.1016/j.jenvman.2011.06.029.
[20]Olajiga O, Ani E, et al. A COMPREHENSIVE REVIEW OF ENERGY-EFFICIENT LIGHTING TECHNOLOGIES AND TRENDS. Engineering Science & Technology Journal 2024;5:1097–111. https://doi.org/10.51594/estj.v5i3.973.
[21]Energy Efficiency Directive n.d. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en (accessed September 2, 2025).
[22]Arik M, Setlur A. Environmental and economical impact of LED lighting systems and effect of thermal management. Int J Energy Res 2010;34:1195–204. https://doi.org/10.1002/er.1639.
[23]Rubinger RM, da Silva ER, et al. Comparative and quantitative analysis of white light-emitting diodes and other lamps used for home illumination. Opt Eng 2015;54:014104. https://doi.org/10.1117/1.OE.54.1.014104.
[24]Franz M, Wenzl FP. Critical review on life cycle inventories and environmental assessments of LED-lamps. Crit Rev Environ Sci Technol 2017;47:2017–78. https://doi.org/10.1080/10643389.2017.1370989.
[25]Castro M, Jara AJ, et al. Smart Lighting Solutions for Smart Cities. 2013 27th International Conference on Advanced Information Networking and Applications Workshops, 2013, p. 1374–9. https://doi.org/10.1109/WAINA.2013.254.
[26]Todorović BM, Samardžija D. Road lighting energy-saving system based on wireless sensor network. Energy Efficiency 2017;10:239–47. https://doi.org/10.1007/s12053-016-9447-6.
[27]Jiang J, To S, et al. Optical design of a freeform TIR lens for LED streetlight. Optik 2010;121:1761–5. https://doi.org/10.1016/j.ijleo.2009.04.009.
[28]Lee X-H, Moreno I, et al. High-performance LED street lighting using microlens arrays. Opt Express 2013;21:10612–21. https://doi.org/10.1364/OE.21.010612.
[29]Public Buildings & the New Energy Efficiency Directive (EU) : Key Changes | Odyssee-Mure n.d. https://www.odyssee-mure.eu/publications/policy-brief/public-buildings-new-efficiency.html?utm_source=chatgpt.com (accessed September 2, 2025).
[30]Vitta P, Dabasinskas L, et al. Concept of Intelligent Solid-State Street Lighting Technology. Elektron Elektrotech 2012;18:37–40. https://doi.org/10.5755/j01.eee.18.10.3057.
[31]Kim DH, Jeon SH, et al. Direct Illuminance-Contribution-Based Lighting Control for IoT-Based Lighting Systems in Smart Buildings. Sustainability 2024;16:5054. https://doi.org/10.3390/su16125054.
[32]Summers JK, Smith LM, et al. A Review of the Elements of Human Well-Being with an Emphasis on the Contribution of Ecosystem Services. Ambio 2012;41:327–40. https://doi.org/10.1007/s13280-012-0256-7.

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